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AUTHOR D'Ambrosio, Ubiratan
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ABSTRACT

This paper notes three objections to the use of hand-held calculators in schools: they would (1) block reasoning, (2) make individuals machine-dependent, and (3) broaden the gap between developed and underdeveloped nations. Each is addressed, with specific examples used to refute them. The belief is strongly expressed that calculators can aid in adjusting social imbalances between "have" and "have not" groups and nations. Projects in Brazil in which calculators are being used are cited. The use of calculators in modeling real problems is also discussed. (MS)

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ISSUES ARISING ON THE USE OF HAND-HELD CALCULATORS IN SCHOOLS

by Ubiratan D'Ambrosio

Most of the objections to the use of hand-held calculators (HHC) in schools may be grouped into three main issues :

1st: HHC will block reasoning and will make individuals mentally slow;

2nd: the use of HHC will make individuals dependent on the machine, and the absence of it will be a handicap for daily needs;

3rd: HHC will broaden the gap between rich and poor, developed and underdeveloped nations.

This talk will be addressed to questions derived from the three issues above. No doubt, there are fundamental questions which may be inserted in the very important branch of WHY's in education.A further question, obviously depending on the one just raised, is HOW. We will touch only briefly the question of "HOW" to use HHC. The WHY question deeply relies on philosophical considerations relating to the overall goals and objectives of mathematical education, and its underlying philosophy is present in the paper. We refer to [1] or to [2] , for an expanded version. The second question, related to "HOW" to use HHC, is the subject of much ongoing research and will obviously have a dynamic character, depending on the adopted philo - sophy of education, in particular of mathematical education,on accept ed societal goals, and on technological advance. Anyhow, we will give a few examples on specific uses of HHC, as well as on some on- going projects, and also reference sources.

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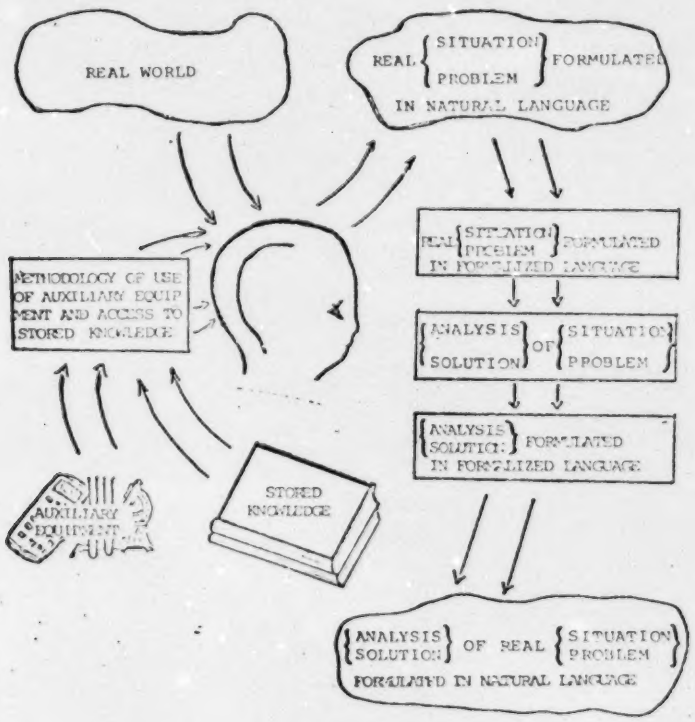
Let us address initially to the first and second objections, which are closely related. A Brazilian colleague of mine once said that "if a child forgets its calculator at home, it will forgets its head". As a preliminary, I must say that this is not the conception I have of the power and potential of a child's head. What, indeed can be said of the power and functioning of a child's mind? Not going into an almost endless discussion of the process of reasoning and creativity, we can briefly say that HHC reproduces, in a very unsophisticated and crude way, some of the basic operative functions of the brain.

In several instances, inventions which are, in a sense, similar to that of HHC, have caused impact and reaction. We might give the word to Plato, in his Phaedrus , which describes a conversation between the young King Theuth and the good old King Thamus, of Egypt, on the subject of the invention of writing. The old King dennounced it as a danger for civilization, saying that children and young people, who used to apply themselves to learn and retain whatever was taught them, would now cease to exercise their memories and consequently would be less diligent and capable.

Similar citations could be mentioned. Probably, the most striking is the rationale of G.W. Leibniz, about his calculating machine. In fact, the operational concept in mathematics is a recent fact, direct consequence of the invention of arabic algarisms, which by no means represent the essence of mathematics, and its inclusion in a course of general studies is even more recent, which was amply discussed in [2]. For long, manipulation of operations had been a merely mechanical ability, done with the aid of instruments or fingers and hands, recently replaced by the mechanical use of Arabic algarisms and positional notation. In other words, this is a mere mechanization of the structurewhich is the basis of positional numeric systems. Indeed, quantitative considerations, which carry the meaning of precise counting only

up to lower two-digit numbers, are always an attribute of qualitative analysis. Linguistic considerations are illustrative of this. We mention, in particular, the recent works on the Inca "quipus", carried on by Marcia and Robert Ascher [3], which imply a strong attribute aspect to quantitative aspects of a discourse.

We regard the process of mentalization of reality in the following simplified scheme:


REAL WORLD
REAL {SITUATION / PROBLEM} FORMULATED IN NATURAL LANGUAGE
METHODOLOGY OF USE OF AUXILIARY EQUIPMENT AND ACCESS TO STORED KNOWLEDGE
{ANALYSIS / SOLUTION} OF {SITUATION / PROBLEM}
{ANALYSIS / SOLUTION} FORMULATED IN FORMALIZED LANGUAGE
AUXILIARY EQUIPMENT
STORED KNOWLEDGE
{ANALYSIS / SOLUTION} OF REAL {SITUATION / PROBLEM} FORMULATED IN NATURAL LANGUAGE

We agree with René Thom's description of mathematics as a finer language than natural language to describe reality.

As mentioned before, and anthropological research reinforces this view, numbers appear with the precision of units only in the lower range. Exemplifying, no one, with the exception of children doing exercises and exames in arithmetics, and of machines ever uses numbers like "1,432,173". When someone needs these numbers, which occur in very specific branches of activities, they are dealt with by mechanical means, be it with the recent electronic equipment or with the mechanical heavy machines of the turn of the century. Meanwhile, the needed and important capability of "wise and experienced" men, which call for good quantitative evaluation, has been entirely subdued by the false importance of calculations precise to the unit! It would be useless to repeat examples of school failure in mathematics which could be avoided by a minimal amount of quantitative common sense. This quantitative common sense has been almost impossible to achieve due to overburdened emphasis on merely mechanical abilities, which undoubtedly do not represent the potential of the human mind. The overall and generalized use of HHC will probably make man less concerned with details of "precision to the unit" and more concerned with global quantitative evaluation. Of course, in some - a few - instances, precision to the unit may be desirable. Then, a HHC or even a larger machine will be needed and properly used.

This brings us to the second issue. The dependence on the machine is, indeed, a false issue. The argument between Kings Theuth and Thamus could be reproduced in practically every moment when a new invention is put into practice. It is remarkable the fact that Arabic algarisms were forbidden by legal edicts in Florence in the close of the XIII century, and I myself remember that when ballpoint pens were introduced, we were not allowed to use them, otherwise our handwriting would be spoiled to the point that we would be unable to write in an intelligent way. Probably, when wrist watches were invented, people would object, saying that "the moment your watches breaks,

you will be unable to distinguish sunrise from sunset". The old always rejects the new. This rejection is probably the most active force against the absolutely needed dynamical character which should prevail in the educational process.

In fact, we brought to discussion a good comparative example for the issue of precise counting. Although in some daily practices, precise timing is needed, and appropriate chronological devices are used, for most of our routine activities unprecise and even intuitive time measurement are satisfactory. No one would dare to say he is sleeping in daytime for the reason his watch is not working! As we said before, the overall and generalized use of HHC will have the effect of changing the forces from "precision to the unit" to global quantitative evaluation. A HHC will always be available to someone, and with the same ease that we borrow a pen from a colleague when we forget ours, or we ask a passerby in the street "What time is it?",we will be able to remedy the situation of not having a HHC at hand when need is felt. It is remarkable to notice the drop in the price of HHC. They are cheaper than books: indeed the cost of a low cost model of HHC goes in the largest part to commercialization.

We now come to discuss the very important issue of what influence will HHC have in social unbalance, which prevail in most countries, and which seems to resist educational efforts. And also about the urgent need of bridging the gap between developed and underdeveloped countries.

In both cases, the local social unbalance or the global world desequilibrium between "haves" and "have nots" can be challenged only by eliminating the striking differences between available basic equipment and abilities. This is the rationale followed by training programs, this was the rationale behind school systems set up by the declining aristocracy to meet the challenge of the professional guilds, and this is the rationale for underdeveloped countries investing most of their human and material resources in education. For more dis -

cussion on this we refer to [2]. Indeed, the objective of all these programs is to prepare generations to compete with adequate abilities and tools. This competition, understood in its broad and global aspect, is the ultimate goal of an evolving society, in its full conception. Be it a lower class family with hopes of their children having better professional opportunities, be it an underdeveloped nation trying to deal and trade with developed nations in more dignifying circunstances. In both cases, it is necessary that the challenger be fully prepared to deal with the established structure, and if not in possession of the full equipment, certainly knowing how effectively powerful this equipment is. By rejecting sophistication in education with the argument of "this is costly" or "we are not yet ready for this", socially unprivileged classes or less developed nations risk perpetuating through the educational system a "status quo" which they must change.The oppressive power of "an absent electronic brain" is much more effective, then the debts which might result from learning that there is not such a thing!

Probably, the young boy in a Peruvian village who, after much effort, learned how to do arithmetic with paper and pencil, goes for a job in a city, and sees the boss pressing a few buttons and getting the results out of that "electronic brain", will experience the same sensation as his ancester warriors who met the gigantic armoured complexes of "Spaniards on horses". They were regarded as single entities!

To introduce HHC in a school system is much more a matter of attitude, and the understandable and expected reaction to its use must be faced. This can be minimized if HHC is allowed to come into use, rather than forced upon a school system. Several strategies may be adapted. A rather successful one is to bring them into playing an important role in teacher training, through modelling courses. See, for example [4] and [5]. HHC must be brought into a useful device for daily practices. Once the teacher

is "liberated" from prejudices and fear of HHC "spoiling minds", the acceptance of the instrument as a companion in daily practices will be conveyed to children. At the same time, evidence of rather immediate advantageous results of the use of HHC in schools may be an important factor. Research projects on HHC, conducted in schools, have the advantage of showing such results. Rather than the results of the research in iself, the main goal is to bring awareness to the use of HHC. In the Institute of Mathematics, Statistics and Computer Science of the State University of Campinas, we conduct a chain of research projects, in classes of 30 to 40 students, in various levels of schooling.

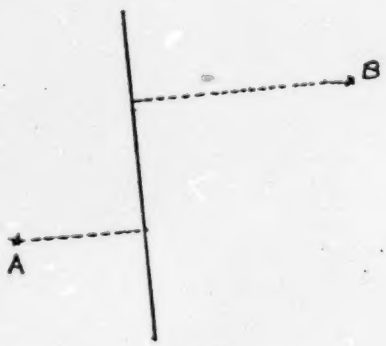
One typical project is being conducted in a lower income private school in the city of Campinas. A class-room of 45 students at the 7th year of Primary School (14 years old) is divided into groups of 15 students. Group A has no access to machines, Group B has limited access to machines (during class period) and Group C has total access to the machines (taking them home). Classes are conducted in the usual way, with the normal program.No change in the attitude of the instructor nor in the choice of curricular material, examples or home work. Three tests are given with intervals of one week, with the same kind of exercises and problems. The attitude of the student is observed and compared, in the course of the experiments.

Although the programatic material is not prepared for the utilization of HHC resources, the general attitude of the student should be affected, in the sense of giving him better and more adequate methodology for the utilization of what we have called "auxiliary equipment". This easiness is dealing with equipment in the analysis of real world problems or situations is the goal we hope to attain with the use of HHC.

In dealing with Mathematical Modelling, the use of HHC may bridge the gap between Mathematics and Applications, at an early stage.Concepts of the Calculus, like limits, derivatives and ap-

proximations find, in the use of HHC a natural vehicle for rather immediate applications. Model building, previously largely restrained to finite mathematics, has the possibility of reaching, through numerical manipulations, continuous phenomena. A few elementary examples are discussed in [4] and [5].

Furthermore, plausible reasoning, as presented by G.Polyá , can be conveniently adapted to bring up a full understanding of hypothesis forming, in the very essence of the axiomatics method.In fact, borrowing from an example amply discussed in [5], we may present, through HHC, the full "mentalization" of analysis and solution of real problem situations. Starting with the example of a life-saver which has to reach a swimmer in trouble in a beach resort, we are able to build up the entire process of formulating hypotheses



which are approximations of a real situation. To bring the situation

from the picture on the left to the diagram on the right represents the very essence of modelling. After this, the use of HHC shows, by simple computations involving solution of right triangles, through Pythagoras' theorem, that the solution of the problem of minimal path is indeed a broken line. The location of the point to "enter into the water" is found through a nesting interval technique. This example puts into effective combination, both the very deep conceptual approach of axiomatics, regarded as a modelling of natural phenomena in the purest line of thought of Euclid, Newton, and others, and the use of numerical methods as a tool for the analysis of the same natural phenomenum modelled into a mathematical problem.

A larger number of examples like the one just described, always close to the reality in which the educational process is taking place, will enable HHC to find its meaningful use in mathematical education. When we say reality we imply cultural and sociological framework, built up in an appropriate motivation for the age group in which the educational experience is taking place. And when we say meaningful use in mathematical education, we mean HHC used not merely as a tool for doing less painfully meaningless computations, but as a companion which can make possible through quantitative manipulation the mathematical analysis of natural phenomena, thus enhancing mathematics in its proper place among the sciences.

Summing up, the use of HHC will allow for the never before experienced power of employing numbers in modelling real problems situations and reaching their understanding.

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